EREAN
EU FP7 Marie-Curie Initial Training Network

Funded by the European Union

Policy Brief Nr. 1

EU FP7 MC-ITN EREAN Policy Brief

NO. 1 • MAY 2015

EU FP7 EREAN training network offers (c)lean recycling solutions for rare-earth magnets

Summary

- EREAN is the European Rare Earth Magnet Recycling Network which started its activities in September 2013. It trains 15 young researchers in the direct and indirect recycling of NdFeB permanent magnets.
- The innovative aspect of the EREAN project is that it addresses the whole materials loop from End-of-Life consumer goods to recycling and the production of new REE magnets, with an integrated life cycle assessment.
- As is highlighted byEuropean Rare Earths Competency Network (ERECON), recycling of REE permanent magnets should receive top priority.
- The automotive sector is likely to become the main consumer of REE magnets in Europe, as it moves towards more Hybrid Electric Vehicles (HEVs) and Full Electric Vehicles (EVs). These magnets also contain dysprosium, arguably the most critical REE.
- Direct recycling routes (alloy reproceing) can offer a cost-effective strategy for recycling REE magnets.
- In the case where direct recycling of permanent magnets is not possible, novel indirect recycling routes can offer solutions. Indirect recycling routes can also be used for dealing with other REE-containing industrial process residues. Further research into leaching, precipitation, solvent extraction and electrochemistry could give the EU a competitive advantage in this area.

Introducing EREAN

EREAN (European Rare Earth Magnet Recycling Network) is the FP7 Marie-Curie Initial Training Network Project that started on the 1st of September 2013. This European Rare Earth (Magnet) Recycling Network trains 15 young researchers in the science and technology of rare earths, with emphasis on the recycling of these elements from neodymium-iron-boron permanent magnets.

An intensive intersectoral and interdisciplinary collaboration has been established in the EREAN consortium, which covers the full materials loop, from urban mine to magnet. By training the researchers in basic and applied rare-earth sciences, with emphasis on extraction and separation methods and rare-earth metallurgy, sustainable materials management, recycling methods, life cycle assessment (LCA), and the principles of urban mining, they will become the much needed "rare earthers" for employment in the growing European rare-earth industry. Erean's Partners. The EREAN Consortium covers the full value chain. EREAN draws it talents from 9 Beneficiaries, including 7 Research Institutes (KU Leuven (coord.), UHelsinki, Chalmers,TU Delft, UOB, Oeko, Fraunhofer) and 2 Companies (Umicore and Solvay-Rhodia). Concurrently, EREAN is strengthened with 6 more (industrial) Partner Organisations, being InsPyro, MEAB, Less Common Metals, Treibacher, Stena and Magneti.

>> The European Rare Earth (Magnet) Recycling Network trains 15 young researchers in the science and technology of rare earths, with emphasis on the recycling of these elements from neodymium-iron-boron permanent magnets. <<

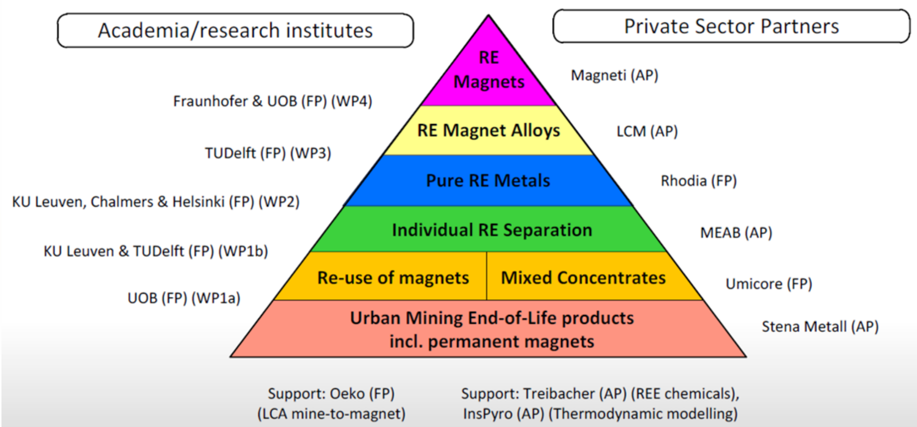

Figure 1: Value chain approach used in EREAN/ from the urban mine to new magnet alloys and new magnets.

Agnieszka Franczak (KU Leuven), ER3 EREAN:

"The EREAN project provides training that enriches the professional skills of researchers working on rare earth recycling. The EREAN project gives also a possibility for personal development by interaction with all the members of the EREAN network, localized in diverse spots in Europe. Different localization, different ways of working, different points of view on the same point of interest - all of these provide ample opportunities for enlarging the basic knowledge needed in the rare earths recycling field, bringing at the same time many ideas for practical recycling solutions and making EREAN one of the most successful projects in the rare earth recycling business in Europe."

EREAN's first research results

The main original and innovative aspect of the EREAN project is that it addresses the whole materials loop from End-of-Life consumer goods to recycling and the production of new REE magnets, with an integrated life cycle assessment. As regards recycling options, EREAN covers both a direct and an indirect recycling route

In the former the magnets are treated as a raw material for the production of fresh magnet alloys and, subsequently, new magnets. In the latter magnet scrap material is transformed to its elemental components. The REEs are recovered from the magnets and separated from each other for use in subsequent permanent magnet production or, possibly, in other existing or new applications such as magnetocaloric materials or lamp phosphors. The first two research accomplishments are:

A hydrometallurgical (indirect recycling) method has been developed, which is adjustable to all NdFeB magnets, regardless of their composition. After completely transforming powdered samples into a sulphate mixture, a suitable selective roasting and water leaching treatment resulted in 95-100 % extraction efficiencies for Nd, Dy, Pr, Gd, Tb and Eu, while Fe remained in the resultant residue forming a marketable hematite-dominated by-product. Impurities other than Fe were also greatly separated from the leachate thereby enabling the production of a liquid with at least 98% REM purity. Such a solution then can be directly treated without pre-treatments for impurity removal. The majority of consumed acid is recyclable resulting in an environment-friendly flowsheet. [**More info: M.A.R. Onal et al., submitted to Journal of Sustainable Metallurgy**]

Concurently an indirect recycling procedure for the efficient extraction and separation of REEs and other valuable elements from used NdFeB permanent magnets has been developed using ionic liquids. Nd_2O_3, Dy_2O_3 and CoO were obtained with purities of 99.6%, 99.8% and 99.8%, respectively. Recycling of the employed ionic liquid for reuse in rare earths separation was also demonstrated. [**More info: S. Riano & K. Binnemans, Green Chemistry, 2015: DOI: 10.1039/C5GC00230C**]

Figure 2: The EREAN team during the network-wide event in Chalmers, Sweden.

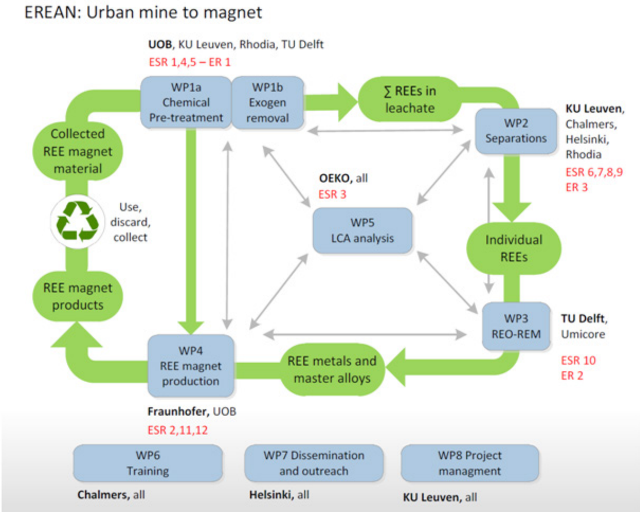

Figure 3: EREAN research methodology covering both a direct and indirect recycling route for NdFeB permanent magnets

The policy relevan ce of EREAN

In 2010 the European Commission (EC) published a milestone report on Critical Raw Materials (CRM) for the EU, in response to the awareness of a supply risk for many raw materials. The rare-earth elements (REEs) were considered to be by far the most problematic. In 2011, the rare-earth crisis came to its peak with a more than tenfold increase in prices of light rare earths (LREEs) and heavy rare earths (HREEs). In 2014 the EC published an update of its CRM report, in which the concern about Europe being able to secure reliable, sustainable and undistorted access to raw materials was repeated. Of the 54 materials under investigation, the HREEs and LREEs were, once more, identified as having the greatest supply risk, with 99% of HREEs and 87% of LREEs being imported from China. The REE magnet industry consumes the major part of the LREEs neodymium (Nd) and praseodymium (Pr), while it consumes practically all of the produced HREE dysprosium (Dy). This makes the REE magnet industry and the various downstream sectors that utilise these magnets in their products and services extremely vulnerable to price fluctuations and shortages.

The automotive sector is likely to become the main consumer of REE magnets in Europe, as it moves towards more Hybrid Electric Vehicles (HEVs) and Full Electric Vehicles (EVs). Furthermore, REE magnets are used in a diverse range of bulk applications incl. aerospace (wing flaps and generators), the medical sector (MRI scanners), metal processing (magnetic separators) and renewable energy technologies (wind turbines). During the rare-earth crisis of 2011, three possible solutions were investigated to alleviate the shortages; (1) increased recycling rates of REE-containing devices; (2) the search for new, mineable REE resources outside China, and; (3) the development of REE-free strong permanent magnets ("substitution"). Although Europe has access to some REE deposits, for instance NorraKärr (Sweden) and Kvanefjeld (Greenland), these mining projects are still at an exploratory stage and it will take many years before these mines become operational. Secondly, the development of new REE-free permanent magnets requires a scientific breakthrough that has not come about, despite decades of research, not only in Europe, but around the world. Therefore, of the three potential options, only the first is likely to succeed from the European perspective on the short to medium term.

Concurrently, in the recently published report of the European Rare Earth Competency Network (ERECON), which was set up under the auspices of DG Enterprise and Industry to lower the REE supply risk for the EU, it is pointed out that research focusing on the recycling of REE permanent magnets is in strong demand. Combining the EU needs and the ERECON "call-for-arms", EREAN, therefore, focuses on recycling solutions for the large quantities of REE permanent magnets.

>> As has been highlighted in the recommendations for policy makers in the final report of the European Rare Earths Competency Network (ERECON), recycling of REE permanent magnets – especially in the automotive sector – should receive top priority. <<

Recommendations

As is also highlighted by ERECON recycling of permanent magnets could provide a valuable source of rare earths for Europe, but several challenges have to be overcome for commercially viable, large-scale REE recycling. Key obstacles to increasing rates of recycling permanent magnets include the lack of information about the quantity of REE materials available for recycling, insufficient and often non-selective collection rates, and recycling-unfriendly designs of many REE magnet containing products. In the near term, opportunities for End-of-Life recycling of REE magnets are largest for hard disk drives and specific assemblies in automotives, where magnets are relatively large and economies of scale can be achieved. Direct recycling routes (alloy reprocessing) could offer a cost-effective strategy for recycling the REE magnets contained in these products. Offshore wind turbines and hybrid and electric vehicles are likely to become key targets for such future REE recycling; currently, however, their potential is still limited due to low market penetration and relatively long lifetimes.

In the case where direct recycling of permanent magnets is not possible, novel indirect recycling routes can offer solutions. The research in EREAN has already pointed out the potential of this route is large. Furthemore, indirect recycling routes can also be used for dealing with other types of REE-containing waste streams, such as bauxite residue, phosphogypsum and many other industrial process residues. [**More info: K. Binnemans et al., Jurnal of Cleaner Production, 99, 2015, 17-38**] More research is required to validate and upscale new processing methods including electrochemical methods and alternative chemistries for REE separation (for example, using ionic liquids in extraction). These various processes, reagents and equipment have to be re-engineered to reach sufficient standards of robustness, yield, safety and cost efficiency for secondary materials, with respect to both magnets and other REE-containing streams. Further research into leaching, precipitation, solvent extraction and electrochemistry could give the EU a competitive advantage in this area.

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Acknowledgements

EREAN has received funding from the European Community's Seventh Framework Programme ([FP7/2007-2013]) under grant agreement n°607411 (MC-ITN EREAN: European Rare Earth Magnet Recycling Network). This publication reflects only the author's views, exempting the Community from any liability". Project website: **www.erean.eu**